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SANITARY LANDFILL COMPACTOR EVALUATION.(U)
MAR 79 D KRAYBILL, B DONAHUE

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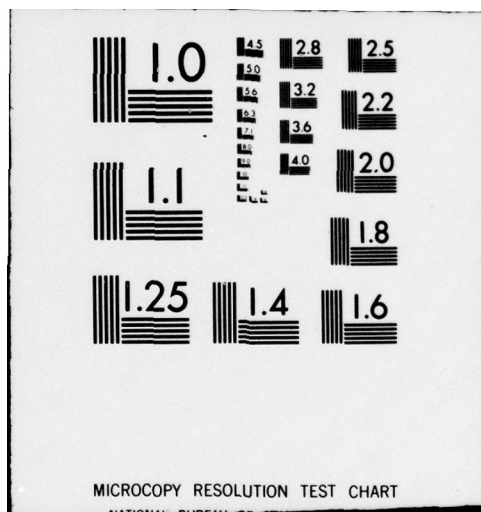
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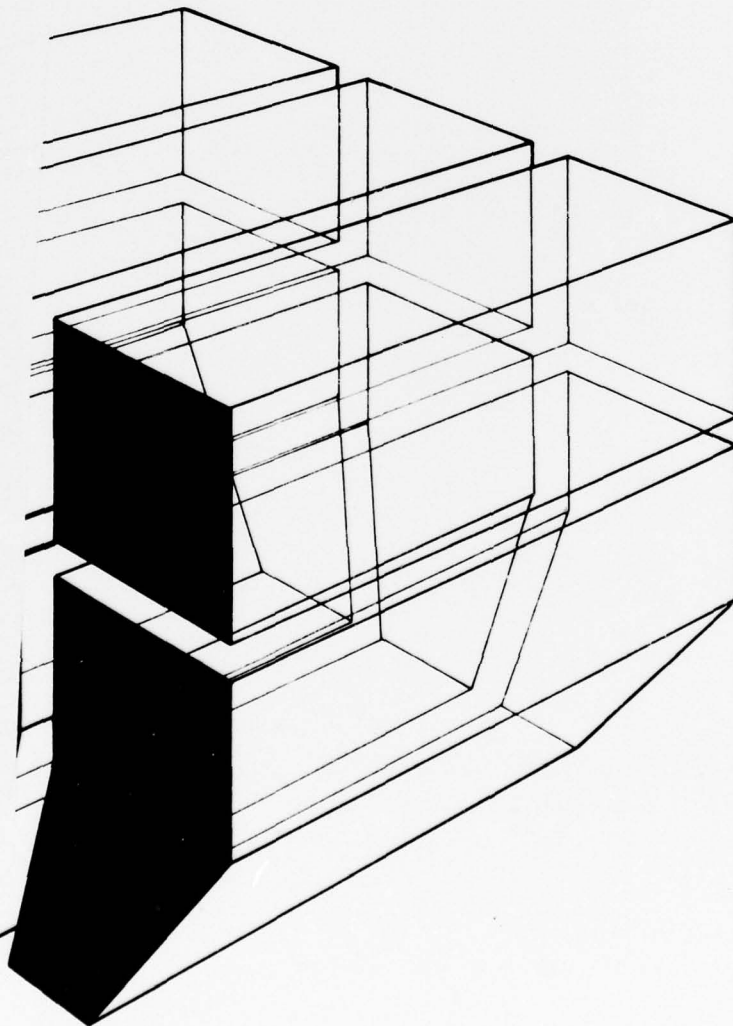
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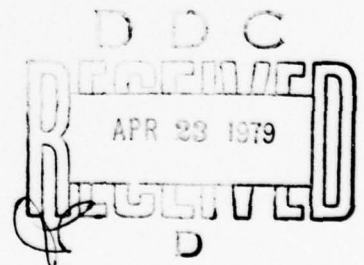
SANITARY LANDFILL
COMPACTOR EVALUATION

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by
Dan Kraybill
Bernard Donahue



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Compacting machinery considered in this report have produced varying results. Research available now indicates that specialized compaction equipment is better than tracked vehicles; however, these compactors usually require an extensive amount of support equipment. Selection of compaction equipment for a military facility will be site-specific, but will depend mostly on the equipment's economic feasibility and the size of the landfill.

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FOREWORD

This study was conducted by the Environmental Division (EN) of the U.S. Army Corps of Engineers Construction Engineering Research Laboratory (CERL) for the Directorate of Military Programs, Office of the Chief of Engineers, under Project 4A762720A896, "Environmental Quality for Construction and Operation of Military Facilities"; Task T2, "Pollution Abatement System"; Work Unit 007, "Solid Waste Management, Recycle, Resource Recovery for Military Facilities." The Applicable QCR is 1.030106(4).

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COL J. E. Hays is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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SANITARY LANDFILL COMPACTOR EVALUATION

1 INTRODUCTION

Background

Solid wastes must be disposed of properly to minimize adverse effects on the environment. During the past 10 to 20 years, it has become apparent that the sanitary landfill is both the most economical method for disposing of solid waste and the method which conforms best to current air and water pollution laws. Many Army facilities have begun using sanitary landfills to dispose of solid wastes. The increased costs and problems associated with establishing a new landfill have made it economically advantageous to extend a landfill's life as much as possible. Sanitary landfilling requires compaction of the refuse to reduce the space it occupies, to reduce the danger of fire, and to make the refuse less accessible to vermin.¹ Specialized landfill compaction equipment has been developed which offers a greater degree of compaction and therefore extends the landfill's life. However, many types of equipment are available, so the Facilities Engineer must be able to choose the machinery that can be used most efficiently and economically at a specific facility.

Objective

The objectives of this study were: (1) to determine the relative advantages and disadvantages of specialized landfill compactors, (2) to examine some of the various types and brands of compactors available, and (3) to provide criteria useful for selecting sanitary landfill compactors.

Approach

Information about sanitary landfill compactors from manufacturers' literature and from textbooks and technical journals was examined and evaluated. The attributes of a cross section of various compactor types were then studied in the field.

Scope

This study examined only compactors which would be applicable to landfills operated by the Department of Defense.

¹D. Joseph Haggerty, Joseph Lo Pavoni, John E. Heer, Jr., *Solid Waste Management* (Van Nostrand Reinhold Company, 1973), p 179.

Another limitation deserves some comment. The various machines used at sanitary landfills must function as a whole system, and their activities must therefore support one another. The decision to purchase a compactor depends on its ability to do jobs other than compaction, such as excavation and spreading of cover material. Determining the need to purchase other landfill equipment is site-specific and therefore beyond the scope of this report.

Mode of Technology Transfer

This information will be transferred to the field through an Engineer Technical Note.

2 COMPACTION

Principles of Compaction

Refuse is compacted twice before being landfilled. It is first compacted at the source when it is placed in a compacting collection truck. Refuse having a density of approximately 150 to 300 lb/cu yd will be increased to a density of approximately 300 to 1000 lb/cu yd (178 to 593 kg/m³)² by the time it is unloaded at the sanitary landfill. At this point, heavy landfill equipment is run over the refuse to compact it further. It is covered with earth at the end of each day and compacted again. The technique used in this process is very important and can make a great deal of difference in the efficiency of compaction. The refuse must be compacted in thin layers because the compaction force decreases as the depth below the surface increases. Thin layers will help expose bulky items such as refrigerators which are not easily crushed.³

Ideal layer thickness will vary according to the weight and compactive force of a given machine. Therefore, given constant loading characteristics, a heavier machine would be able to provide a larger layer thickness and operate more quickly, while a small machine (or one with less ideal loading characteristics) would have to use thinner layers to provide proper compaction. Under no circumstances should layer thickness exceed 2 ft (.6 m).

²Wayne D. Trehwitt, "Dispelling Compaction Myths," *Waste Age* (October 1976), pp 2-6, 44.

³Christopher Klink, "Achieving Higher Density in Landfill Through Machine Application," *Waste Age* (September 1975), pp 33-34, 36.

It is important that bulky items such as cabinets, stoves, and refrigerators be thoroughly crushed. This is most easily done by placing the item on a relatively hard surface before crushing. It is also important that all areas of exposed refuse receive the proper compactive force. The operator should move the machinery back and forth across the fill to avoid leaving areas uncompacted.

Although the degree of slope has been a topic of debate, the most popular view is that compaction should be done on a 3-to-1 slope. It is assumed that this will force the operator to spread the refuse in thin layers, since larger layers will prevent the machine from going up the incline. There is a fallacy in this approach, however, since the more steeply sloped the incline is, the less direct downforce will be exerted on the refuse layer (Figure 1). A thin layer of refuse will be compacted more efficiently if the slope is less steep.⁴

The number of passes which must be made over the refuse is also widely disputed. The number of passes required to properly compact the refuse will depend mostly on the type of refuse and how thickly it is spread. For example, refuse which consists mostly of wet paper or fiberboard will compact very tightly and very quickly, while a dry waste will be more springy and difficult to compact.⁵ Generally, with a skilled operator and good machinery, three or four passes should be sufficient. After that, a point of diminishing returns is reached quickly, whereby each additional pass provides less and less additional compaction.⁶

Additional compaction can also be provided by properly rotating support machinery and collection tracks. If the roads to the active section of the fill are routed over the completed, covered sections, this additional final compaction will contribute to the final stability of the landfill. (Care must be taken to insure that the final cover is not displaced, which would expose the refuse.)

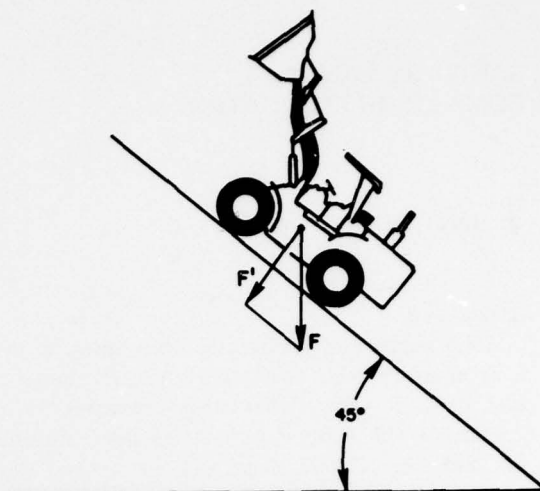
Machinery Used for Compaction

Three basic types of machinery have been used for compaction in sanitary landfills: (1) tracked crawlers, (2) rubber-wheeled loaders and dozers, and (3) steel-wheeled compactors (see Figures 2, 3, and 4). Each has specific advantages and disadvantages, and each is useful in the overall work scheme of a landfill.

⁴Wayne D. Trehwitt, p 6.

⁵Christopher Klink, p 36.

⁶Wayne D. Trehwitt, p 6.



F = WEIGHT OF COMPACTOR

F' = COMPACTIVE COMPONENT OF COMPACTOR WEIGHT

$$F' = F \cos 45^\circ = 0.707 F$$

IF THE ANGLE IS 0° THEN F = F'

Figure 1. Relation of slope to downforce.

Tracked Vehicles

Tracked vehicles are used extensively in landfills to clear ground, excavate trenches and cover material, transfer cover material, and compact refuse. Their greatest advantage is that they possess great traction. Their greatest disadvantage in terms of compaction ability is that they are not designed to compact what they run over. The weight of the machine is spread over the rather large area of its tracks, rather than being concentrated over a small area, which provides maximum flotation of the machine over the surface it is compressing. This increases traction and helps keep the machine from getting stuck, but is exactly the opposite of what a design for maximum compaction would be.⁷

Rubber-Wheeled Vehicles

Rubber-tired vehicles have the advantage of speed. Although they are used for compacting refuse and sometimes for excavating, they are best applied in

⁷E. T. Conrad, "Standards for Selection of Sanitary Landfill Equipment," *Solid Waste Management* (November 1971), pp 18, 24, 26.

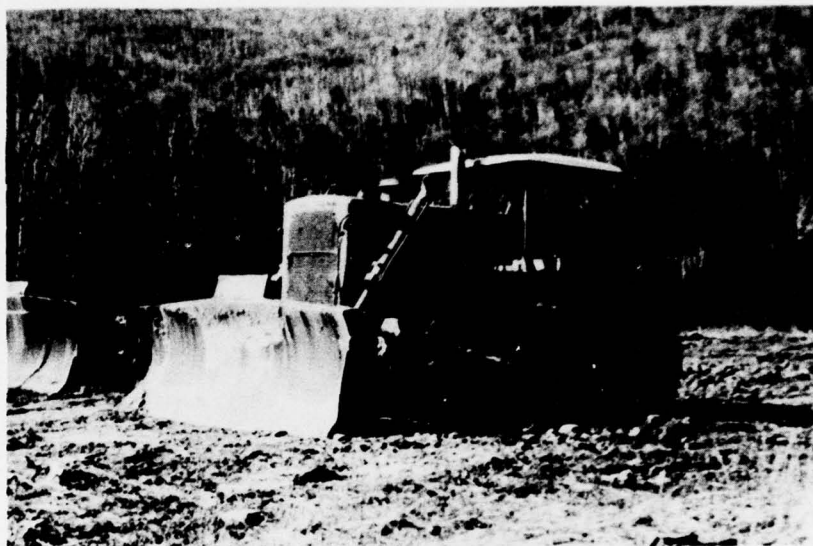


Figure 2. Tracked crawler.



Figure 3. Rubber-wheeled vehicle.



Figure 4. Steel-wheeled compactor.

transfer stations and where refuse or cover material must be moved over intermediate distances. The biggest disadvantage of a rubber-tired vehicle in terms of compaction ability is that the tires can be punctured or damaged from sharp or hard objects in the refuse; use of foam-filled tires can alleviate this problem. Another disadvantage is that these vehicles frequently become stuck.

Steel-Wheeled Vehicles

In terms of sheer compactive ability, steel-wheeled compactors have the best design of the three types of vehicles, because their design provides the maximum concentration of the vehicle's weight on the landfill surface. Their greatest disadvantages are that they lack the traction necessary to perform excavation, and that they are not suitable for hauling cover material over great distances. They are specialized machines that are not well suited for many tasks other than compaction. Therefore, a landfill compactor would be a poor choice for a small landfill having only one piece of equipment.⁸

Landfill compactors have evolved into basically two types of vehicles: those with closely spaced cleats on their steel wheels (Figure 5), and those with widely

spaced cleats (Figure 6). These cleats concentrate the vehicle weight on the very small surface area of the cleat. When cleats are large and closely spaced, the vehicle will ride up on the cleats, significantly concentrating the load and increasing compaction efficiency. However, this system tends to build up material between the cleats. One solution has been to install cleaning bars on the machine (Figure 7) to scrape away the built-up material. The greatest disadvantage of this system has been that it requires energy (i.e., more fuel) to overcome the additional friction imposed by the cleaner bars. Also, if these bars are mounted too low, they will tend to close and impose even more friction on the vehicle.

A second solution to the build-up problem has been to install the cleats in a more widely spaced pattern (Figure 8). This eliminates the need for cleaning bars, thus making the machine somewhat more economical and trouble-free to run. However, this wide spacing results in the machine being somewhat less efficient in compaction, since the cleats tend to penetrate the refuse rather than ride up on it. Compactors with widely spaced cleats also seem to have slightly better traction than those with close cleats and cleaning bars.⁹

⁸"What to Look for When Picking Landfill Equipment," *Solid Waste Management* (October 1976).

⁹Wayne D. Trewhitt, pp 2-6, 44.



Figure 5. Steel-wheeled vehicle with closely spaced cleats.



Figure 6. Steel-wheeled vehicle with widely spaced cleats.



Figure 7. Cleaning bars.

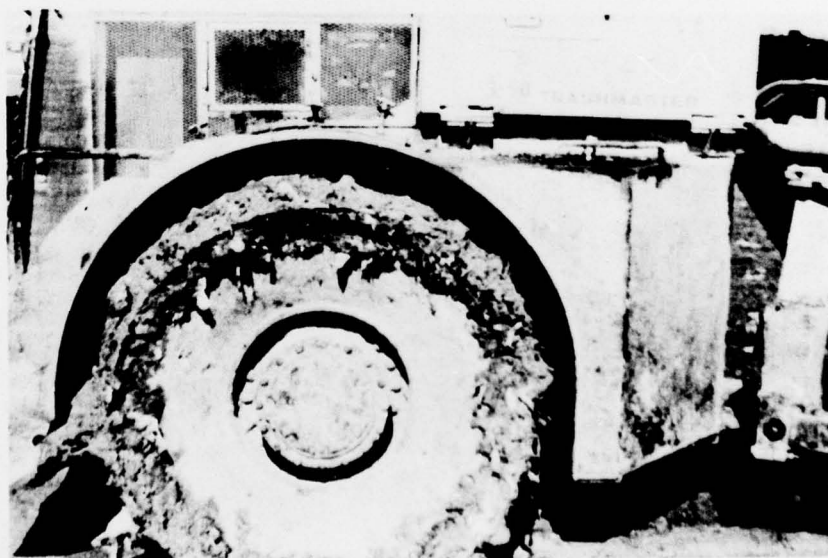


Figure 8. Easy-to-clean, widely spaced cleats.

3 CASE STUDIES

Several studies have compared different types of compactors, tracked vehicles, and rubber-tired vehicles, with varying results. One such study¹⁰ compared a Caterpillar D-9, a tracked vehicle, with steel-wheeled and rubber-tired versions of an FWD Wagner SF-17. Separate tests were run for the steel-wheeled and rubber-tired vehicles, using the performance of the Caterpillar D-9 as a control. The in-place density of the refuse was calculated based on the weight of the refuse placed in the landfill cells being compared and the surveyed volume of those cells. Table 1 shows the results of this test. It is interesting to note that use of the steel-wheeled compactor increased compaction by approximately 11 percent over the tracked vehicle, but the rubber-tired vehicle yielded no significant improvements.

Table 2 provides data pertaining to costs of equipment operation. The most important part of this data is the cost of operation of the various machines in terms of dollars per hour. The steel-wheeled compactor is nearly half as expensive to operate as either of the other machines.

In terms of machine performance, the Stone and Conrad study confirmed that a tracked vehicle was more versatile for performing general tasks around the landfill, while the compactors performed more efficiently in the task for which they were specifically designed.

The Stone and Conrad study noted two adverse effects of installing steel wheels: (1) more power was required to drive the equipment, and (2) the operating speed of the vehicle was reduced. These phenomena would be expected in light of the fact that the steel wheels would sink more deeply into the refuse than a rubber-tired or a tracked vehicle.

Another study, performed at Cape Girardeau, MO,¹¹ compared the performance of a 40-ton tracked vehicle having a 270-hp engine to that of a 16-ton landfill compactor having a 145-hp engine. The tracked vehicle provided densities of 960 lb/cu yd, while the compac-

tor provided densities of 1200 lb/cu yd (712 kg/m³) (a difference of 20 percent). These measurements were obtained in a manner similar to those taken in the test performed by Stone and Conrad.

The Cape Girardeau study shows that the total weight of the vehicle applying the weight of compaction is not as important as the manner in which the weight is applied. This study did not provide comprehensive records of cost data.

A third study compared compactors having widely and closely spaced cleats with a tracked crawler.¹² Table 3 presents the data from this report. The table shows the apparent advantage in efficiency of compaction provided by the closely spaced cleats.

A study¹³ comparing several types of compactors with one another and with rubber-tired and tracked vehicles yielded very optimistic results. Table 4 shows that the best compactor gives nearly 100 percent more compaction than a tracked vehicle.

These four studies show a great deal of variation in the results of tests that were supposedly the same. The results of the tests conducted by Stone in California and by Brateley in Great Britain also characterized the type of waste being compacted (see Tables 5 and 6). Most significant were differences in the proportion of paper products and food wastes. The California study also includes a category of yard wastes which did not occur in the Great Britain study. It might therefore be surmised that paper and grass clippings provide a surface which is springier and more difficult to compact to account for the large difference in compaction rates between the two tests. This could not be stated as fact, however, unless directly comparative compaction tests of the two types of waste were performed.

The information found so far indicates that specialized compaction vehicles provide 10 to 20 percent more compaction than tracked vehicles; however, this conclusion was based on findings of the three studies which used domestic wastes generated by American households, and these wastes are not necessarily similar to those produced by households in other countries.

¹⁰Ralph Stone and E. T. Conrad, "Landfill Compaction Equipment Efficiency," *Public Cleansing* (November 1976), pp 591-598.

¹¹"Landfill Compaction Study at Cape Girardeau, MO," *Waste Age* (September 1976), pp 14-16.

¹²Wayne D. Trehwhitt, "Dispelling Compaction Myths," *Waste Age* (October 1976), pp 2-6, 44.

¹³Keith J. Brateley, "A Description of Comparative Performance Tests of Mobile Plant on a Major Landfill Site," *Solid Wastes* (February 1977), pp 57-80.

Table 1
Density of Landfill Cells
 (From Ralph Stone and E. T. Conrad, "Landfill Compaction Equipment Efficiency,"
Public Cleansing [November [1976] Reprinted with permission of
 Institute of Solid Wastes Management, London, England.)

Test Period		Cell Number	Equipment	Refuse Before Placement of Soil Cover, lb/cu yd		Refuse After Placement of Soil Cover, lb/cu yd		Final, Including Soil Cover, lb/cu yd	
From	To			Wet	Dry	Wet	Dry	Wet	Dry
7/67	11/67	1	Crawler Tractor	1497	921	—	—	—	—
10/67	12/67	2N	Crawler Tractor	1199	561	1318	605	1525	852
11/67	1/68	2S	Rubber-Tired Compactor	1115	538	1252	601	1468	844
8/67	10/67	3	Crawler Tractor	1052	804	1209	924	1610	1250
8/67	10/67	4	Rubber-Tired Compactor	1090	785	1220	878	1570	1208
3/68	7/68	5	Crawler Tractor	1094	706	1186	765	1455	1028
3/68	7/68	6	Steel-Wheeled Compactor	1285	824	1364	875	1660	1162

Table 2
Cost of Equipment Operation
 (From Ralph Stone and E. T. Conrad, "Landfill Compaction Equipment Efficiency,"
Public Cleansing [November [1976] Reprinted with permission of
 Institute of Solid Wastes Management, London, England.)

Description	Crawler Tractor 7/67 to 9/68	Rubber-Tired Compactor 7/67 to 1/68	Steel-Wheeled Compactor 2/68 to 9/68
Maintenance, Fuel, Repairs (dollars)	12,835 ¹	3,480 ²	1,603 ³
Labor @ \$5.40/hr inc. 23% Fringe Benefits, 40-hr/wk (dollars ⁴)	14,040	6,552	7,488
Depreciation @ 6% Interest			
Capital Cost (dollars)	45,000	50,000	50,000
Life, Years	6	10	10
Annual Rate (dollars/yr)	9,151	6,794	6,794
Amount (dollars)	11,439	3,963	4,529
Total Cost (dollars)	38,314	13,995	13,620
Operating Time (hours)			
Per Meter Reading ⁵	1,604	567	911
Less 10% Idle Time	160		
Actual Operating Time	1,444	567	911
Unit Costs (dollars/hr)	26.53	24.68	14.95
Average Rate for Spreading and Compacting Refuse (tons/hr ⁶)	35	30	35
Unit Costs (dollars/ton)	0.76	0.82	0.43

- NOTES: ¹ The crawler tractor had new tracks in November 1965; it is expected that the tracks will be replaced in 1969. No cost for this future expense was included. Equipment was bought used.
- ² Includes one-third of the \$4,148 cost to recap the four tires. Unit bought new.
- ³ Steel wheels were installed in February 1968. The \$11,791 cost for steel wheels was excluded.
- ⁴ Average rate for equipment operators; excludes occasional overtime; includes time the equipment is not operating.
- ⁵ During operator coffee breaks, lunch hour, etc., the compactor engine is shut off. When the crawler tractor is stopped for short periods, the engine is allowed to idle.
- ⁶ Rates based on total tonnage worked and total equipment operating hours, which include time for all landfill tasks.

Table 3
Compaction Test Results—
Mountain View, California Sanitary Landfill,
April 16, 1976
 (From Wayne D. Trehitt, "Dispelling Compaction Myths,"
Waste Age [October 1976]. Reprinted with permission of
 Three Sons Publishing Co.)

	City of Mountain View Refuse	City of San Francisco Refuse
Lb/cu yd		
In-Place Density		
Crawler Tractor	1096	1080
Landfill Compactor	1116	1011
Tamping Foot Compactor	1437	1220
Machine Weight		
Crawler Tractor	105,000 lb	
Landfill Compactor	74,290 lb	
Tamping Foot Compactor	68,850 lb	

Table 4
British Report Data
 (From Keith J. Brateley, "A Description of Comparative
 Performance Tests of Mobile Plant on a Major Landfill Site,"
Solid Wastes [February 1977]. Reprinted with permission
 of Communication Channels, Inc.)

IN PLACE DENSITY OF REFUSE AND COVER

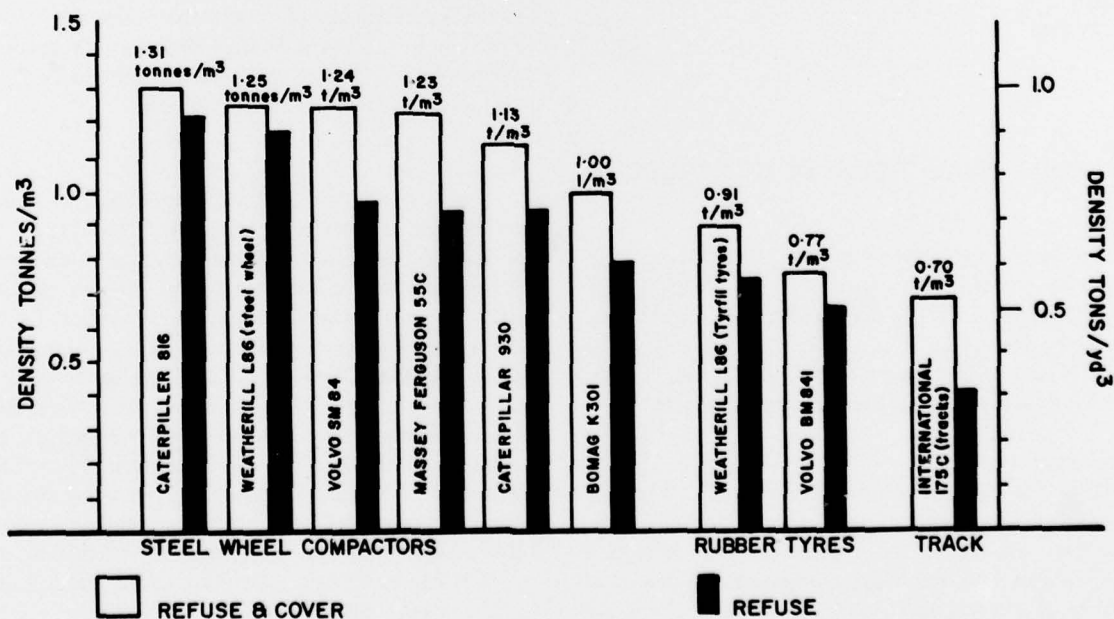


Table 5**Stone Report Waste Characteristics**

(Information taken from Ralph Stone and E. T. Conrad, "Landfill Compaction Equipment Efficiency," *Public Cleansing* [November 1976]. Reprinted with permission of Institute of Solid Wastes Management, London, England.)

	% by weight
Paper and Paper Products	51
Grass and Yard Rubbish	36
Inerts and Miscellaneous	11
Food Scraps, Vegetables, and Food Trimmings	2

Table 6**British Report Waste Characteristics**

(Information taken from Keith J. Brateley, "A Description of Comparative Performance Tests of Mobile Plant on a Major Landfill Site," *Solid Wastes* [February 1976]. Reprinted with permission of Communication Channels, Inc.)

	% by weight
Screenings Below 2 cm	14.78
Vegetable and Putrescibles	27.94
Paper	24.03
Metals	10.68
Textiles	3.90
Glass	11.48
Plastics	5.37
Unclassified	1.87
	100.00

support vehicles consisting of one tracked vehicle, one crane, and one road grader. The compactor had been purchased new in 1975.

Several standard operations were observed, including light excavation, compaction, and moving of cover. The machine seemed to have good traction under all conditions and could climb intermediate grades easily. It crushed heavy-gauge metal objects relatively easily; for example, a 55-gal (209-L) drum which had been run over was quite flat. The inspectors did not observe the compactor being used for heavy excavation, although the operator claimed that the machinery had the capability.

The compactor did not visibly ride up onto the refuse but rather penetrated it. Some springback of the refuse was observed after compaction. As discussed previously, this type of compactor does not have cleaning bars, so some build-up of dirt and refuse was noticed on the wheels. Most noteworthy was that the 55-gallon (209-L) drum (see previous paragraph) jammed onto the cleats of one of the wheels. It is not clear whether the drum would have been removed by cleaning bars or whether it would have destroyed them.

Records of the machine's operating costs were not available at the time of the inspection; however both supervisors and operators were pleased with this model's performance and said that they would purchase another when it became necessary. It was estimated that this model improved compaction by 20 to 30 percent over that of tracked vehicles.

4 FIELD EVALUATION OF COMPACTORS

To observe the abilities of various compactors, four types were observed in the field: (1) a Caterpillar 816, (2) a Rexnord 3-50, (3) a Raygo Rampak 45, and (4) a Koehring-Bomag K301. The Caterpillar and Rexnord models have widely spaced cleats, and the Rampak and Koehring-Bomag models have closely spaced cleats.

Caterpillar 816

The Caterpillar 816 (Figure 6) was used on a landfill that received approximately 90 tons (82 mt) of refuse per day, which consists of a small portion of industrial wastes and no hazardous materials. The compactor, which was operated full time (2000 hr/yr), had

Rexnord 3-50

The Rexnord 3-50 (Figure 9) was being used in a landfill that received approximately 250 tons (227 mt) of refuse per day from predominantly domestic sources. It operated with a large number of support vehicles, including two tracked vehicles and a scraper. During the inspection, conditions were extremely muddy, which made it difficult for the compactor to be used even on the landfill surface; however, the only problem was slight wheel spin and the compactor did not become stuck. The cleats of the Rexnord penetrated the refuse rather than riding up onto it. The refuse was very wet and compacted very quickly. Inspectors did not observe the compactor performing any excavation, but both the operator and supervisor said it was not efficient for such tasks.



Figure 9. Rexnord 3-50 compactor.

The lack of cleaning bars did not seem to hinder the movement of the wheels, since they stayed relatively clean. The cleats were wearing down rather quickly and would soon have to be replaced. This would require cutting off the old cleats with a torch and welding new ones into place.

No records of operating costs were available during inspection. Overall, however, the supervisors and operators were pleased with the Rexnord's operation and said they would purchase another.

Raygo Rampak 45

The Raygo Rampak 45 (Figure 10) was an older model that had been bought used. The landfill received about 150 tons (136 mt) of refuse per day, of which approximately 60 percent was industrial wastes. The support equipment included one tracked vehicle, a 1-1/2 cu yd (1.1 m³) crane, two scrapers, and a dump truck.

The weather on the day of inspection was very rainy and muddy, which adversely affected the traction of the vehicle, causing it to spin its wheels and nearly get stuck. The major reason for this problem seemed to be that the trunnions, the bars to which the blade was attached, were mounted too low, which caused the machine to ride up out of them. This problem has been corrected in newer models. However, the model being observed would visibly ride up onto the refuse and then sink into it, seemingly supplying a great deal of compaction. Although the operator claimed that the compactor could do some light excavating, the inspectors did not observe such activity. The cleaner bars were very effective, keeping the wheels clean even under very muddy conditions. The cleats were badly worn, but their caps could be replaced by cutting and welding (Figure 11). One problem noted was that hoisting or heavy wire can easily wrap around steel wheels and stop the machine. Maintenance figures showed that this particular machine cost \$10.17/hr to run.

Koehring-Bomag K301

The Koehring-Bomag K301 (Figure 12) was operating in a landfill that received 200 tons (181 mt) of refuse per day, which included a fairly large portion of industrial waste. This industrial waste consisted largely of plastics, packing materials, auto interior parts, and wire cable.

The compactor was being operated full time, having as support vehicles a rubber-tired loader, a tracked vehicle, and a scraper with a 15 cu yd (11.5 m³) capacity. It had been in use approximately 4-1/2 months at the time of inspection. The vehicle, which was operating in dry, nearly ideal conditions during the inspection, was equipped with closely spaced cleats and cleaner bars (Figure 6). The machine was observed riding up onto the cleats, sometimes leaving a visible pattern in the refuse it had just compacted. Very little springback of the refuse was observed. However, the inspectors noted a slight wheel spin (indicating a lack of traction) and that the machine seemed to labor occasionally to get through a pile of refuse. The operator stated that the machine could do light dozing, but was rather inefficient at it. The machine seemed to crush heavy-gauge metal objects very easily. Overall, the vehicle seemed to be operating quite satisfactorily.

This machine was being rented for \$2000 per month from a heavy equipment company, which was responsible for repairs. At this rate, assuming a usage rate of 2000 hours per year, total operating costs would be \$12/hour.



Figure 10. Raygo Rampak 45 compactor.



Figure 11. Cutting and welding to replace caps on Raygo Rampak 45.



Figure 12. Koehring-Bomag K301 compactor.

Summary

Generally, the above machines all seemed to function very well. Realistic operating costs seemed to range between \$10 to \$15 per hour, which compares very favorably with the operating costs of a rubber-tired or tracked vehicle.

The vehicles with widely spaced cleats seemed to have slightly more traction than those with closely spaced cleats, while the latter seemed to have a slightly better compaction ability. All of the compactors appeared to need the extensive support equipment that they used. Table 7 provides overall data on all of the machines inspected.

5 CRITERIA FOR EQUIPMENT SELECTION

Whether specialized compaction equipment is feasible at a particular landfill will always be decided by money; i.e., "Does this machine save us money or cost us money?"

Depending on vehicle type and site characteristics, a compactor can only perform a few of the following functions required at a landfill: (1) receiving refuse and vehicles, (2) spreading refuse, (3) compacting refuse, (4) excavating cover material, (5) transporting cover

material, (6) spreading cover material, (7) compacting cover material, and (8) shaping and grading.¹⁴ A compactor cannot realistically be expected either to excavate or to transport cover. The type of vehicle needed for excavation greatly depends on the type of material being excavated. For example, a dragline or crane might be required for tough or rocky soil. While a compactor might be able to do some light excavation in an emergency, this task is normally given to a tracked vehicle; as a result, tracked vehicles are essential for operating a landfill.

Transporting cover material may require several kinds of equipment. The prime requirement of this task is the ability to move cover material quickly and efficiently. Given the amount of material to be moved and the distance over which it must be moved, one must choose the most appropriate vehicle for the task. Over distances of less than 300 ft (90 m), a tracked vehicle would be sufficient to transport the required cover material, but for distances of more than 300 ft (90 m), a faster machine is necessary. Tables 8 and 9 list applications for various machines.¹⁵

¹⁴Christopher Klink, "Considerations for Landfill Equipment Applications and Operational Efficiency," *International Waste Equipment and Technology Exposition Official Proceedings* (June 1975), pp 207-211.

¹⁵Richard W. Eldrege, "The Selection of Sanitary Landfill Equipment," *Waste Age* (January/February 1974), pp 28-30, 55.

Table 7
Inspection Data
(Metric Conversion Factor: 1 lb = .4 kg)

	Rexnord	Caterpillar	Raygo	Koehring-Bomag
Type*	1	1	0	0
Weight (lbs)	51,500	40,900	43,500	38,000
Operating Costs (\$/hr)	\$12.00**	not available	\$10.17	\$12.00

*1 = widely spaced cleats; 0 = closely spaced cleats

**As claimed by salesperson

Table 8
Equipment Selection Guidance for Multiple Unit Sites
(From Richard W. Eldrege, "The Selection of Sanitary Landfill Equipment,"
Waste Age [January-February 1974]. Reprinted with permission
of Three Sons Publishing Co.)

	Loader	Dozer	Compactor	Track	Rubber	Dragline	Backhoe	Truck	Motor Grader
Spread Refuse	A	A	A	0	0	0	0	0	0
Compact Refuse	A	A	A	0	0	0	0	0	0
Excavate Cover	A	A	0	A*	A*	A	A	0	0
Haul Cover									
300 ft. (90 m) or less	A	A	B	A	0	C	C	C	0
300 to 1000 ft. (90 to 300 m)	C	0	0	A	B	C	C	C	0
More than 1000 ft (300 m)	C	0	0	0	A	C	C	C	0
Spread Cover	A	A	A	B	B	0	0	0	B
Compact Cover	A	A	A	0	0	0	0	0	0
Shape Cover	B	B	B	B	B	0	0	0	A

A - Excellent choice

B - Secondary choice

C - "In-combination only" choice

0 - Not applicable or poor choice

* - Scrapers may require loading assistance in tough soils and adverse weather conditions

Table 9
Equipment Applications
 (From Richard W. Eldrege, "The Selection of Sanitary Landfill Equipment," *Waste Age*
 [January-February 1974]. Reprinted with permission of Three Sons Publishing Co.)

	Compaction	Flotation	Resistance to Abrasive Materials	Earth Movement 300 ft (90 m) or Less	Up to 600 ft (180 m)	Traction Under Wet and Slippery Conditions	Excavation of Soils Granular	Tough Cohesive	Weathered Rock	Blade Width and Loading Capability	Ability to Provide On-Site Construction Assistance	Ability to Easily Provide Off-Site Assistance	Ability to Resist Puncture of Tires
Track Dozer	3	1	3	2	2	1	2	1	1	1	1	3	1
Track Loader	3	1	3	2	2	1	2	1	1	2	1	3	1
Rubber-Tired Dozer	2	2	1	1	2	3	1	2	2	1	1	1	3
Loader	2	2	1	1	1	3	1	2	2	2	1	1	3
Compactor (Steel-Wheeled)	1	3	2	2	3	1	3	3	3	1	3	3	1

Key: 1 - Highly Rated for the Item Listed
 2 - Rated as Medium Abilities for Listed Item
 3 - Rated Low in Ability for the Identification Item

Note: These ratings are relative. A "3" rating does not indicate inability as much as greater problems in attaining the desired result. This greater effort may include the preparation of site or equipment, additional passes of equipment to obtain good results, or the operation of equipment at extremely low production rates.

Another important factor when considering whether to buy a compactor is the size of the sanitary landfill. If the landfill is so small that only one piece of equipment is required, then that piece of equipment must be able to perform all of the tasks required.

When a new piece of equipment is going to be purchased, the economics of the various alternatives should always be analyzed. The alternatives for most landfills are many and varied, and a precise analysis of the capabilities and drawbacks of every possible type of equipment combination is beyond the scope of this report. However, the following example shows how economic analysis methods can be used in a very simple case.

A sanitary landfill is considering the purchase of a new piece of equipment and has the choice of buying either a landfill compactor or a tracked dozer. They have just purchased a new dozer, which would be the support vehicle for the compaction machine. The purchase price of the tracked dozer is \$135,000, and its operating costs are \$25 per hour. The compactor costs \$105,000, and its operating costs are \$12 per hour. Over the 10,000-hour (5 years) life of the machine, the compactor could be expected to conserve approximate-

ly 15 acres of land, providing a savings in purchase and development costs of \$5000 per acre. In addition, a rubber-tired front-end loader must be purchased to support the landfill compactor by excavating and hauling cover. This loader costs \$60,000, and its operating costs are \$20 per hour. It has a useful life of 5 years.

The Facility Engineer computes the equivalent yearly cost, considering interest rates. The two alternatives compared are (1) buying another dozer, using the two dozers together, and paying for an additional 15 acres of land; or (2) buying a compactor and front-end loader and saving the money that would otherwise be spent on additional land. Interest rates are 9 percent.

For alternative 1, the yearly costs would be:

$$E_1 = \text{cost of another dozer} = \$135,000 \times (a/p)^9$$

$$Q_1 = \text{operating cost for the dozer} = \$25/\text{hr} \times 2000 \text{ hrs}$$

$$L_1 = \text{cost of additional 15 acres} = \$10,000 \times 15 (a/p)^9^{16}$$

¹⁶James L. Riggs, *Economic Decision Models* (McGraw-Hill, 1968).

$(a/p)_5^9$ is a multiplication factor for the time payment of a gross amount at 9 percent for 5 years. $(a/p)_5^9 = 0.25709$. Yearly cost of alternative 1 = $\$135,000 \times 0.25709 + 2000 \text{ (hr/yr)} \times 25 \text{ (\$/hr)} = \$150,000 \times 0.25709 = \$123,270.65/\text{year}$.

For alternative 2, the yearly costs would be:

$$E_2 = \text{equipment costs for compactor and loader} \\ = (\$105,000 + \$60,000) \times (a/p)_5^9$$

$$Q_2 = \text{operating cost for compactor and loader} \\ = \$12/\text{hr} + \$18/\text{hr}$$

$$\text{Yearly total cost} = \$30/\text{hr} \times 2000 \text{ (hr/yr)} + \$165,000 \\ (a/p)_5^9 = \$60,000 + \$165,000 \times 0.25709 = \$102,419.05/\text{yr.}$$

According to this analysis, it would be more economical to purchase two pieces of equipment and save money on the land. It should be noted that this is a very simple example, and an actual situation would be much more complex.

6 CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Each of the three major types of compaction equipment used at sanitary landfills has specific advantages and disadvantages. Tracked vehicles possess great traction, but are not designed to compact what they run over. Rubber-wheeled vehicles have the advantage of speed, but their tires are subject to puncture or damage from sharp objects. Steel-wheeled vehicles have great compactive ability, but lack the traction necessary to perform excavation and are not suitable for hauling cover material.

Studies of various types of compactors have produced a variety of results. Information available at this time indicates that specialized compaction vehicles provide 10 to 20 percent more compaction than tracked vehicles. It appears that all of the specialized compactors require some type of support equipment.

Selection of compaction equipment for use at a sanitary landfill is site-specific, but depends mostly on the equipment's economic feasibility and the size of the landfill. Before purchasing equipment, the prospective buyer should make a precise economic analysis of the various equipment alternatives available.

Recommendations

It is recommended that the information in this report be used to select the appropriate compactor and support equipment for sanitary landfill operations.

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